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SNOW CHARACTERIZATION MEASUREMENTS AT SNOW ONE-A,(U)

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9. SNOW CHARACTERIZATION MEASUREMENTS AT SNOW ONE-A

by

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ABSTRACT

SNOW CHARACTERIZATION MEASUREMENTS
AT SNOW-ONE-A

Measurements documenting the characteristics of naturally falling snow are being conducted to form a statistical base as input to the precipitation modeling efforts of the Cloud Physics Branch at AFGL. The major part of the 1981-82 winter operations were held in conjunction with the CRREL sponsored, tri-service, SNOW ONE-A field experiment at Camp Ethan Allen in Jericho, VT. This report summarizes the AFGL snow characterization measurements taken during SNOW ONE-A.

Three new instruments, designed and built at AFGL to measure the fall velocities of individual snowflakes, the short-term variations in snowfall rates and to determine the crystalline structure of the prevailing snow, are described. Discussions are given on the overall operation of each instrument and examples of the resulting data are shown. Available results are listed in tabular form together with a preliminary data quality assessment. The initial analysis of the measurements taken during the storm of January 31, 1982 are also presented.

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SNOW CHARACTERIZATION MEASUREMENTS
AT SNOW ONE-A

1. INTRODUCTION

Snow characterization measurements by the Cloud Physics Branch (LYC) of the Air Force Geophysics Laboratory (AFGL) during the SNOW ONE-A field experiment were conducted as part of LYC's hydrometeor modeling efforts. The decision to participate in the experiment was based on the exchange of data; that our measurements may be of benefit to other participants and that we may be able to use the results of others as input in our modeling.

The LYC's borrowed trailer arrived at Camp Ethan Allen (CEA) three days behind schedule after a series of frustrating delays in activating a balky heating system. Two of the primary instruments were immediately installed and put into operation. The third primary device arrived the following week. These three instruments were conceived, designed and built at AFGL during the summer and fall months of 1981. Although they were tested in the laboratory, their installation at CEA provided the first exposure to winter operating conditions. As a consequence, the initial experimental phase was a combination of operator familiarization and instrument testing. As expected, the quality of acquired data improved as the experiment progressed.

The purpose of this initial report is to define the results obtained by LYC during SNOW ONE-A. Section 2 (fall velocity indicator), 3 (snow rate meter) and 4 (belt reader) give brief descriptions of the instruments under our primary effort and a discussion on the operation and data acquisition. A more detailed AFGL engineering report on these three devices will be forthcoming in the fall.

The instruments considered under our secondary effort failed to produce any results. Conversion of the aircraft Knollenberg 1-D probes into a ground-based measuring device never materialized because of time and personnel commitments. The ground spectrometer, although installed at CEA, proved susceptible to freeze-up, thus produced little useful data.

Section 5 lists the dates and times that data are available. The assessment of data quality is based on a "quick-look" analysis and is subject to change when a more in-depth study is conducted. A more comprehensive analysis of these data will be the subject of a AFGL report which should be published by late fall.

Section 6 gives results from the storm of 31 Jan 82, since this event produced the longest period of simultaneous measurements of the three primary instruments.

2. FALL VELOCITY INDICATOR

The initial version of this instrument was conceived, designed and built at AFGL in 1980 for the purpose of recording the physical characteristics of naturally falling snow. The instrument was redesigned in 1981 incorporating the lessons learned in the initial testing and construction and was completed just in time for SNOW ONE-A.

This device (Fig. 1) uses video recording to continually monitor snowflakes as they fall through a viewing area of 3 x 3 cm^2 with a field depth of 1.5cm. Two strobe lights, located below the lower corners of the viewing area, combined with the reflection from two mirrors just above the upper corners give fairly uniform lighting throughout the sampling volume. The strobe lighting produces multiple frontal images on single

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video frames enabling fall velocities to be determined from knowledge of the flash rate and measurement of fall distance. The upper portion of the video frame shows a reflected image from a mirror angled to give a downward looking view of the falling flakes. This combination of front and top views give information as to orientation characteristics (tumbling, oscillation, etc.), crystal type, size and fall velocity.

Since the FVI was conceived to record falling snow as contrasted to blowing or wind driven snow, it was purposely designed to limited use in situations where the horizontal component of the fall trajectory is 45 degrees or less than vertical.

Thus far, the reduction of these data is a slow process of hand analysis involving photographic reproduction of selected video frames from which the measurements are made. Three images of a 3.64 mm (largest dimension) dendritic snow flake are shown in Fig 2. Five images of a 1.28 mm particle thought to be graupel are evident in the left portion of the photograph of Fig 3, with two images of another (.86 mm) on the right. The differences in image intensities, with the lower image being the most intense, is attributed to a slight misalignment of the strobe flash tubes. The bright rectangle in the upper portion of the photographs is the reflection from the angled mirror looking down upon the particles. The brightness of this reflection tends to mask the particle images and could also be the fault of the flash tube positioning.

The fall velocity of the flake in Fig 2 was calculated to be 1.18 m/s. The particle on the left side in Fig 3 gave 1.28 m/s with the other giving .87 m/s. Analyzed fall velocity data from the storm of 31 Jan 82 are listed in tabular form in Section 6.

3. SNOW RATE METER

Snow rate, or the amount of snow deposited on a surface in a given amount of time, is one of the basic standards used to describe the intensity of falling snow. Values of this nature are usually determined from weight or depth readings taken at relatively long time periods (hours or large fractions thereof). Short term variations (minutes), which are essential in studies such as electromagnetic attenuation, are thus masked in the normal measurements.

The snow rate meter (Fig. 4) was specifically designed and constructed at AFGL to delineate short-term variations in snow rate. This device utilizes an electronic balance sensitive to .01 gram and has remote operating capabilities allowing the instrument to be situated free of obstructions effecting naturally falling snow. The remote sensing head was enclosed in a heated compartment with the weighing platform and collection bucket situated on a connecting rod above the heated cavity. The graduated, clear-plastic bucket was enclosed by a wind screen which, as in the case of the FVI, was designed to allow the measurement of falling snow with trajectories of 45 degrees or less than vertical. Larger angular paths caused by winds of high velocity create a pumping effect which, in most cases, prevents the snow from settling in the bucket. A snow fence was installed in a 3 meter diameter around the instrument to disrupt the more severe horizontal wind components to protect the equipment from wind damage. Digitized weight measurements at ~2.7 second intervals were recorded on a computer tape for later analysis. Periodic evaluation of the amount of snow deposited in the collection bucket gives some indication as to snow density.

This device, as expected with any new instrument, had its own unique

set of problems. Initially, the on-off action of the thermostat controlling the temperature of the remote sensing head caused unacceptable drift in the output. When that problem was corrected, an electronic failure resulted in complete break down. A rushed repair by the balance manufacturer over the holiday shutdown period allowed operations to resume again in January. Binding between the connecting rod and the guiding bearing caused some data inconsistancies. When these problems were finally resolved, the meter worked well.

One of the major concerns with this instrument was the unknown effect of wind action on a balance of this sensitivity. Test runs were conducted during periods of high winds and preliminary analysis indicates that wind action poses no serious problems. Turbulent wind effects show on the data plots as spikes but tend to form a uniform envelope about the base line. Computer averaging of the 2.7 second data can thus be used to determine the absolute readings.

Plots showing weight vs time and equivalent rate vs time for the storm of 31 Jan, are shown in Section 6.

4. BELT READER

This instrument was built at AFGL during the fall months and wasn't actually completed until one week after the commencement of SNOW ONE-A. It was designed specifically for the characterization of crystal type for an attempt to relate snow of particular crystalline form with changes in electromagnetic attenuation, fall velocity, density, etc.

This device (Fig. 5) consists of a moving belt which transports captured snowflakes into the view of a video camera. Strobe lighting

provides multiple images of a 1.5 cm^2 field per frame and records them on video tape. The instrument has the ability to sample on a continuous basis and provided sufficient magnification to identify the internal structure of individual snowflakes.

The reader performed flawlessly in laboratory tests and provided excellent images of the cubic structure of sodium chloride crystals. Installation in the winter environment of CEA proved to be a different story. Freeze-up of the gear drive, belt difficulties in material composition and path drift required continual on-site alterations. The problems were identified and corrected wherever possible allowing some data to be recorded although the overall operation nor quality of images ever equaled that of the laboratory tests.

Figures 6 and 7 are examples of the data recorded on the storm of 31 Jan. Figure 6 shows four strobe illuminated images of an irregular shaped particle as it was transported across the viewing area at 1905:33 on 31 Jan 82. The largest dimension of this particle is ~ 1.5 mm. The cross type crystal in Fig 7, possibly crossed columns, was captured at 1927:49 and is ~ .9 mm in length. The ~ .4 mm particle (lower image) is probably graupel. A descriptive synopsis of the data taken during this storm is presented in Section 6.

5. DATA SUMMARY

Table 1 lists the dates and times for which data are available for the SNOW ONE-A field experiment. Measurements were attemped on other dates not included in this listing but because of wind conditions and/or lack of sufficient snowfall, no data were recorded.

Date	Instrument	Time	Remarks, Data Quality
9 Dec 81	FVI	0830-1030	Fair
		1500-1700	Fair
	Bal	1500-1700	Poor to Fair
	Belt	---------	Instrument not on site
16 Dec 81	FVI	0000-0845	Fair
	Bal	---------	Electronic Malfunction
	Belt	0030-0200	Poor to Fair
		0300-0330	Poor to Fair
13 Jan 82	FVI	1600-2120	Fair
	Bal	1645-2218	Fair to Good
	Belt	1600-2120	Fair
29 Jan 82	FVI	1112-1209	Poor to Fair
	Bal	1119-1210	Fair to Good
	Belt	1112-1208	Poor to Fair
31 Jan 82	FVI	1612-2047	Good
		2100-2125	Good
	Bal	1610-2130	Good
	Belt	1826-2125	Fair to Good

Table 1. Summary of Available Data Taken by the Cloud Physics Branch of AFGL During the SNOW ONE-A Field Experiment.

As previously stated, data assessment is based on preliminary analysis and is subject to reclassification upon a more comprehensive scrutiny.

6. DATA - 31 JANUARY 1982

Figure 8 is a weight-time plot starting at 1610 on 31 Jan 82, which shows the actual 2.7s raw data received from the electronic balance. Figure 9 is a rate-time plot from the first stage analysis of the data in Fig. 8. The rate in millimeters per hour is in terms of equivalent melted water since, as of this time, the density of the prevalent snowfall has not been determined. In this analysis, the raw data is averaged using a running mean technique with the averaging period depending upon and de-

termined from the variability of the raw data over the complete sampling period. A 5 minute averaging period was used in this analysis. This type plot clearly shows the short-term variability in snow rate over the course of the storm.

Tables 2 through 6 are listings of particle sizes and their corresponding fall velocities determined from the [illegible] video data taken during the intensive measurement periods on 31 Jan. Size is a measurement of the particle's longest dimension. Distinguishing characteristics, if any, are listed in the remark column. These tables list just a representative sampling from the designated periods since time does not allow a complete analysis.

Time	Size mm	Fall Vel. m/s	Remarks
1700	3.86	1.12	
to	5.23	1.28	
1715	1.7	1.13	graupel
	.86	.59	graupel
	3.86	1.18	graupel
	2.14	.95	graupel
	1.28	.87	
	1.28	.62	graupel
	1.71	.95	graupel
	.86	.59	graupel

Table 2. Fall Velocity Measurements During the Time Period of 1700-1715 on 31 Jan 82

Time	Size mm	Fall Vel m/s	Remarks
1800	1.7	.80	graupel
to	6.4	1.39	dendrite
1815	1.29	.67	graupel
	.86	.82	graupel
	6.0	.85	stellar
	2.14	.59	stellar
	7.28	1.08	dendrite
	4.29	.77	stellar
	3.86	.62	stellar
	3.0	.62	dendrite

Table 3. Fall Velocity Measurements During the Time Period of 1800-1815 on 31 Jan 82

Time	Size mm	Fall Vel. m/s	Remarks
1900	2.14	.72	graupel
to	1.93	1.03	graupel
1915	2.57	1.23	graupel
	1.51	.62	graupel
	2.14	.87	column
	2.19	1.23	graupel
	.51	.62	graupel
	1.28	.67	
	3.43	1.08	dendrite
	2.57	1.28	dendrite

Table 4. Fall Velocity Measurements During the Time Period of 1900-1915 on 31 Jan 82

Time	Size mm	Fall Vel. m/s	Remarks
2000	.64	.62	graupel
to	.43	.59	graupel
2115	1.28	.59	dendrite
	3.64	1.31	
	3.0	1.28	dendrite
	5.14	1.16	stellar
	1.37	1.03	graupel
	2.57	1.18	graupel
	.86	1.41	graupel
	1.71	1.08	graupel

Table 5. Fall Velocity Measurements During the Time Period of 2000-2015 on 31 Jan 82

Time	Size mm	Fall Vel. m/s	Remarks
2100	1.7	1.05	
to	.85	.92	graupel
2115	1.07	.62	
	1.50	.87	
	.43	1.59	

Table 6. Fall Velocity Measurements During the Time Period of 21100-2115 on 31 Jan 82

Table 7 gives visual descriptions of the snow particles recorded by the belt reader during the three intensive measuring periods that the instrument was operating.

(1900-1915) - Predominantly irregular shaped crystals, possibly graupel
- Occasional dendritic and columar forms.

(2000-2015) - No clearly definable type - appears to be mixture of grapel or irregular particles with occasional dendrite and stellar forms.

(2100-2115) - Mixture of graupel and dendrite - light intensity.

Table 7. Description of the snow particles during the intensive measurement periods 1900-1915, 2000-2015 and 2100-2115 on 31 Jan 82.

7. CONCLUDING REMARKS

Although these new instruments did not operate as well as we had hoped and the data was not as high a quality as envisioned, we are quite pleased with the results of our efforts. Steps are now being taken to correct the deficiencies that surfaced during SNOW ONE-A. Updated versions of these instruments should be ready for operation before the next winter season.

It is our intent to publish an AFGL report giving a more comprehensive analysis of the SNOW ONE-A data. We are aiming for a publication date in

Nov 82, which depends heavily upon the availability of time and people for the data reduction.

As a final note, any field program, even as small as ours, involves a number of people. In respect to the data presented herein, the most important contributions were from the Cloud Physics technical staff who conducted the operation at CEA - Anthony J. Matthews, MSgt Stephen D. Crist, SSgt Dennis L. LaGross and CMSgt Donald J. MacDonald. Extended efforts were also given by Barbara A. Main in the analysis of the video data and by Keith Roberts of the Digital Programming Services Inc. in the computer analysis.

Congradulations to R. Redfield and the CRREL Organization for a successful field experiment.

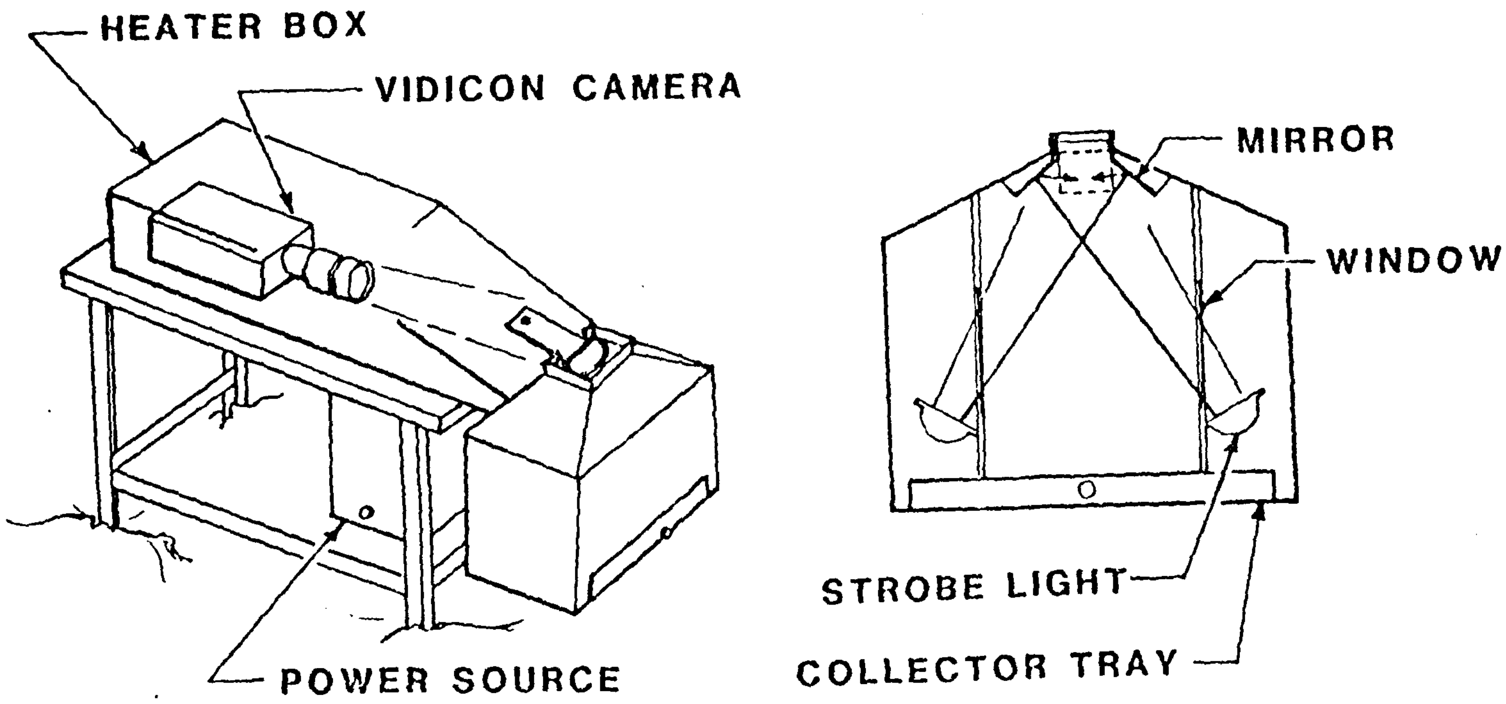

Fig. 1 Diagram of Fall Velocity Indicator.

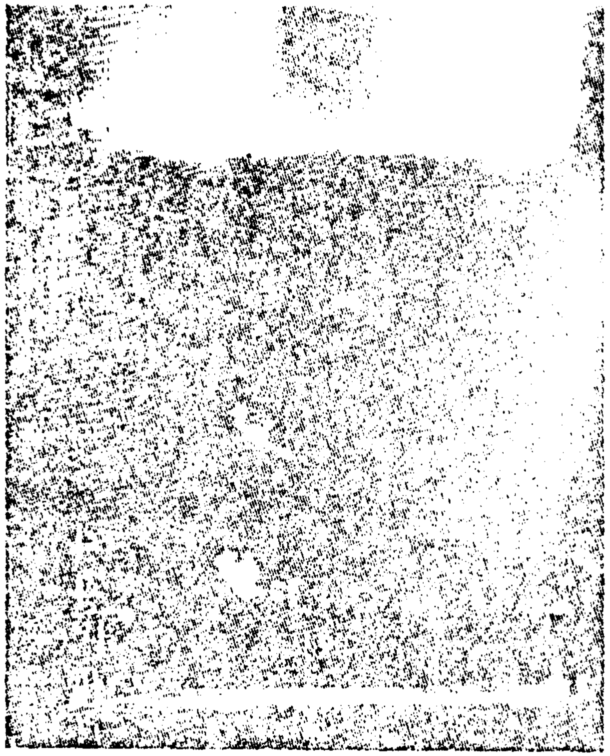

Fig. 2 Photograph of Single Video Frame from FY1 During Measurement Period 1700-1715 on January 31, 1982.

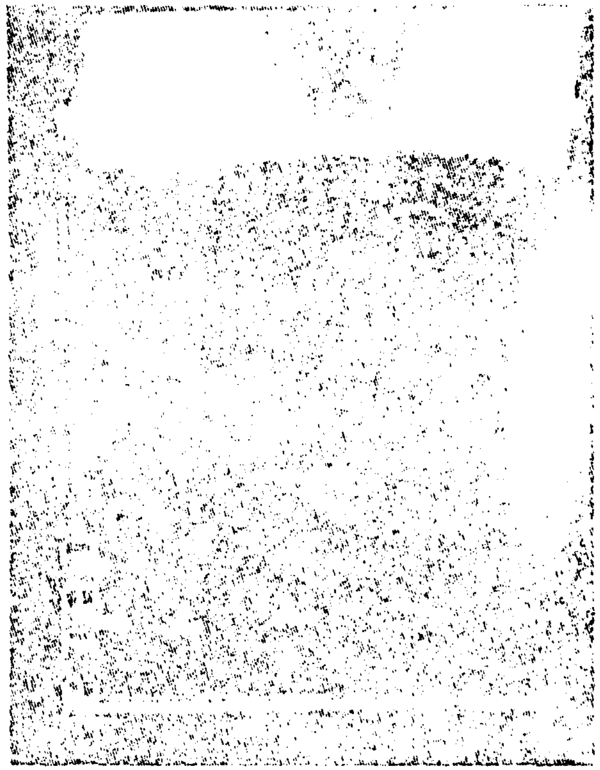

Fig. 3 Photograph of [illegible] Video Frame From FY1 During Measurement Period 1800-1815 on January 31, 19[illegible].

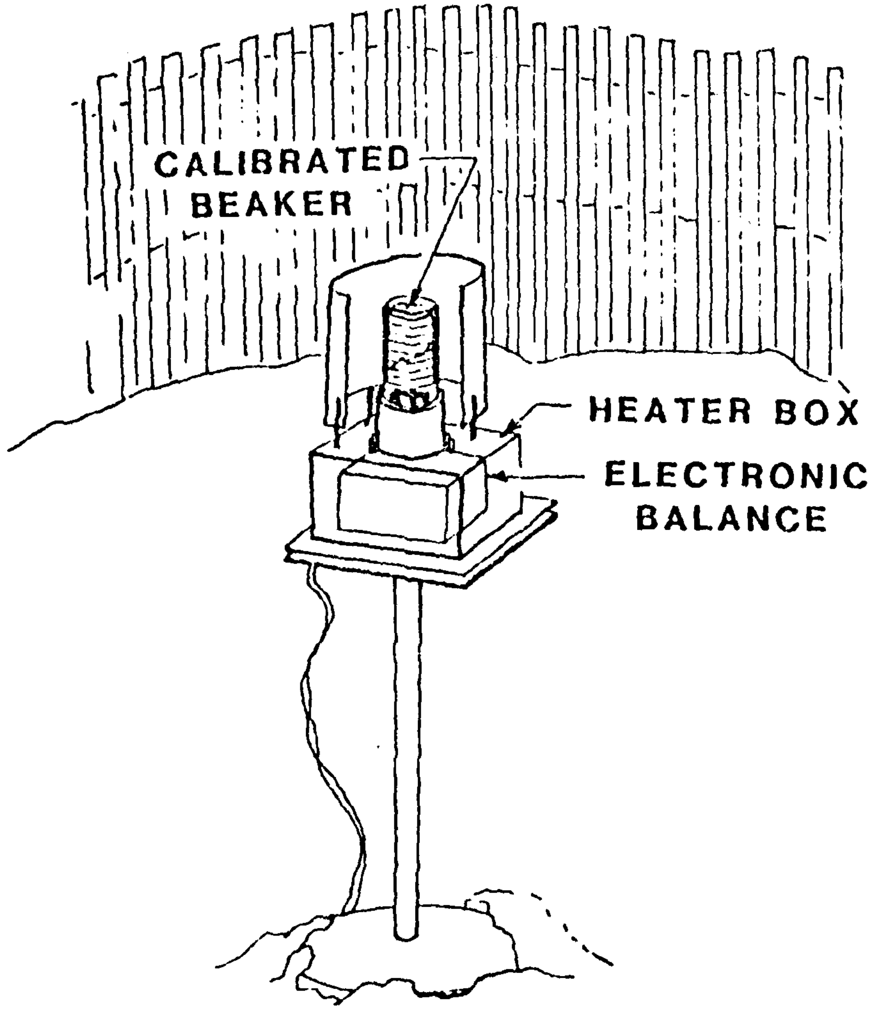

Fig. 4 Diagram of Snow Rate Meter.

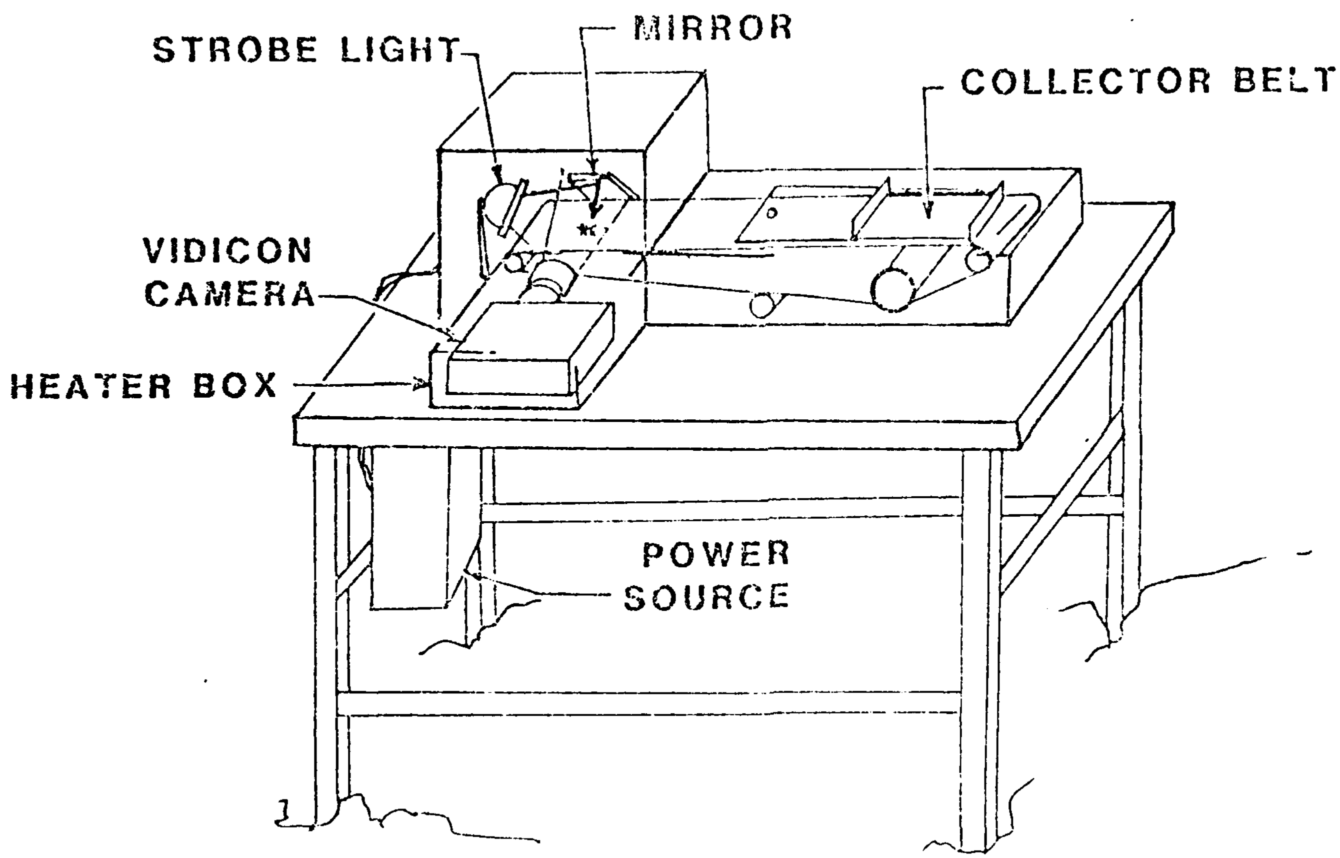

Fig. 5 Diagram of Belt Reader.

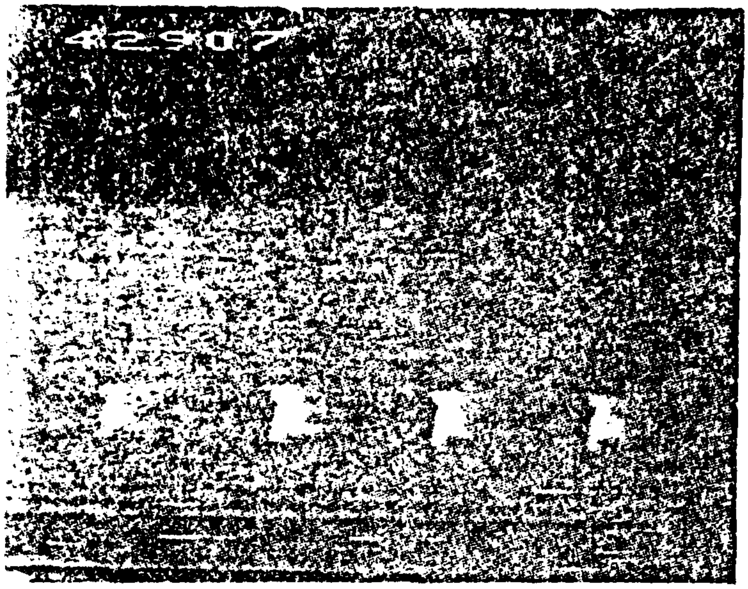

Fig. 6 Photograph of Single Video Frame from Belt Reader on January 31, 1982 at 1905:33.

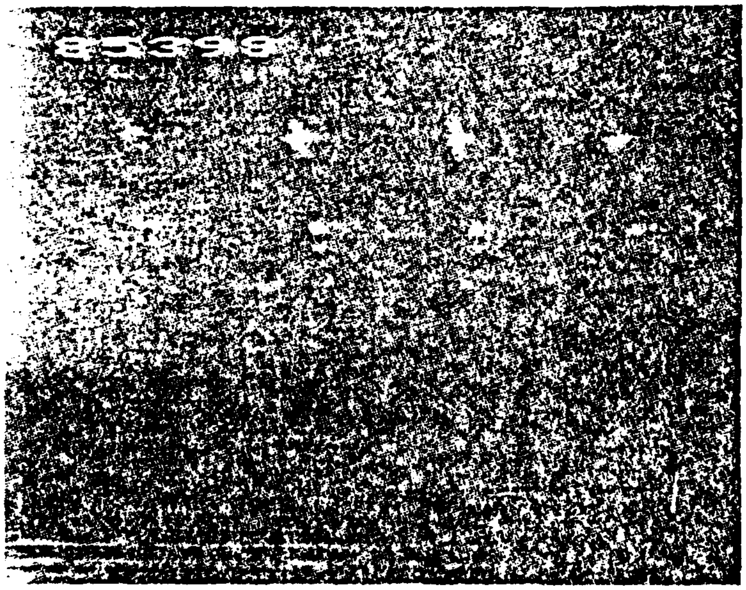

Fig. 7 Photograph of Single Video Frame from Belt Reader on January 31, 1982 at 1927:49.

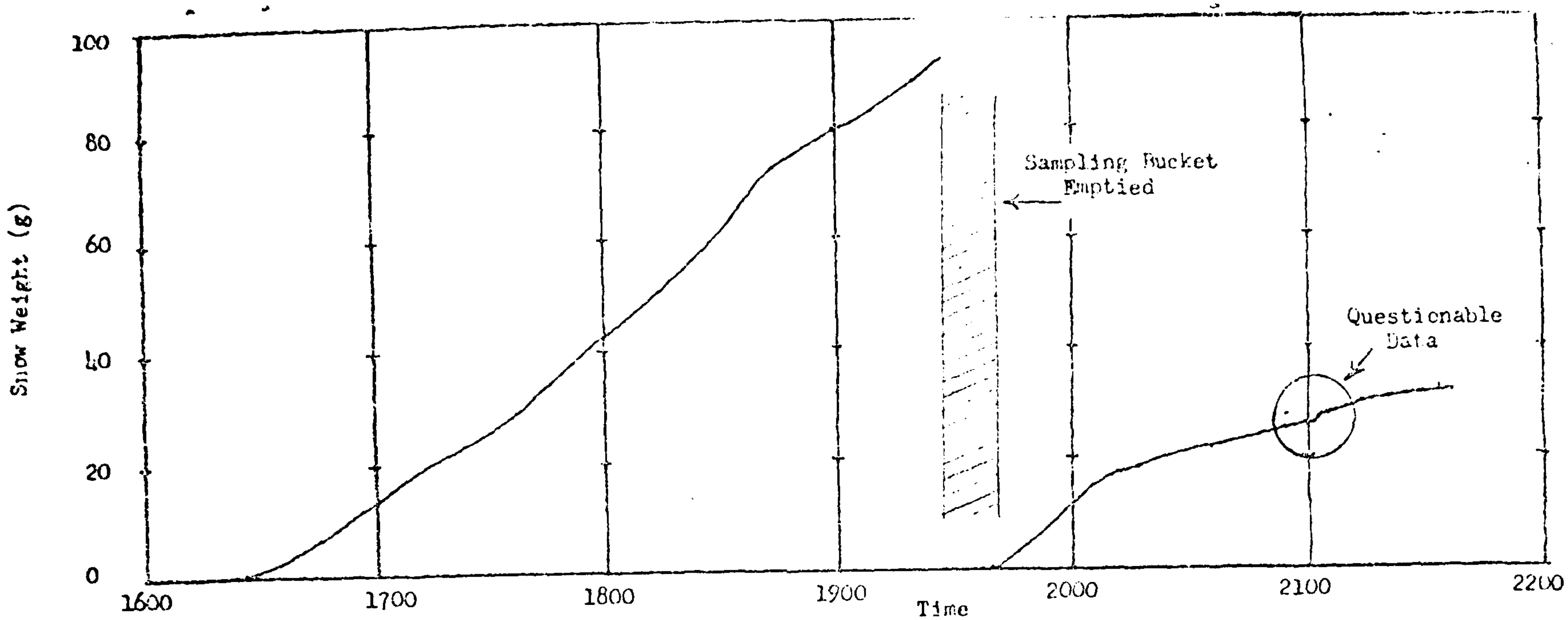

Fig. 8 Weight-Time Plot of Snowfall on January 31, 1982.

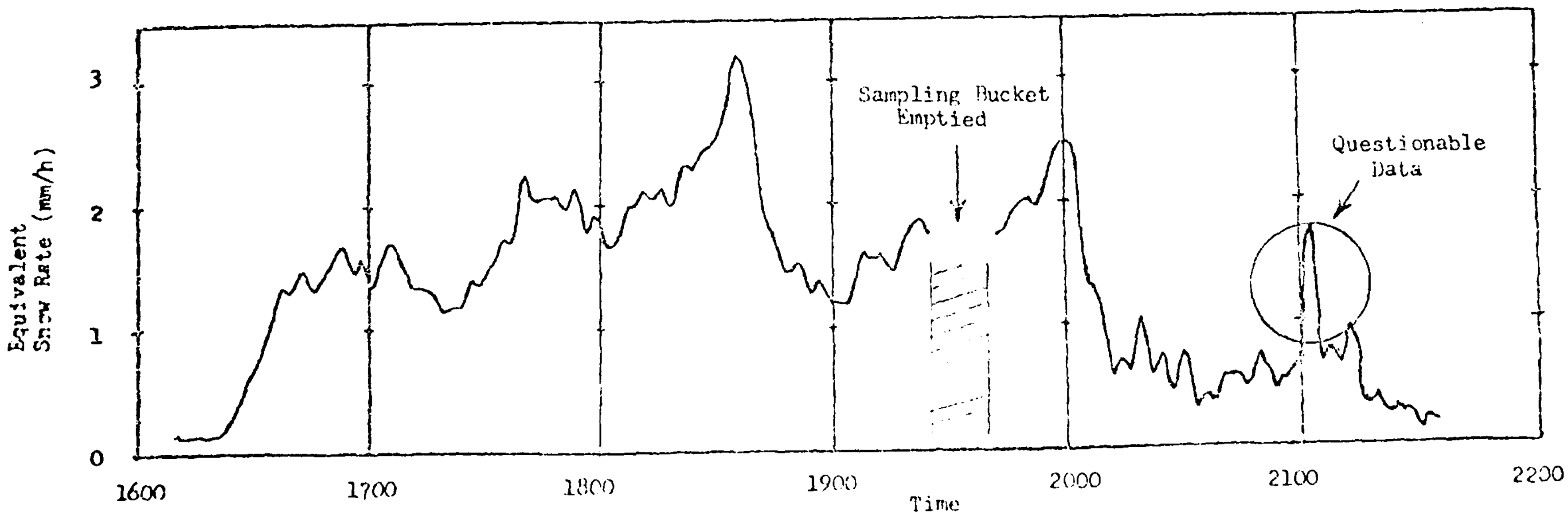

Fig. 9 Rate-Time Plot of Snowfall on January 31, 1982.

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Snow characterization
Fall velocity
Crystal type
Snow rate

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